1.3.4. ON-FARM RESEARCH AND STATISTICAL INFERENCE

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INTRODUCTION

The basic objective of Farming Systems Research (FSR) is to enhance the effectiveness of agricultural research in order to improve the welfare of farm families. On-farm research (OFR) is an important component of FSR and its main function in crop and animal improvement is the testing of component technologies (e.g. varietal and fertilizer trials on crops, feed additives for dairy cattle). In the FSR activities under the BIOCON Project, OFR is done only after an identification of farmers' problems, production constraints and screening of potentially useful technologies. This helps to ensure that OFR will have the best chances of being useful to the largest possible number of farm families. OFR supports the FSR approach by determining whether a new technology is appropriate to the needs of rural households and whether it is compatible with existing systems. OFR thus offers the opportunity to study technical, economic and social effects, and their interactions. The planning of OFR requires consideration of the characteristics of rural households including economic status, decision-making, social relationships and gender division of labour. While traditional researchers might hope to detect statistically significant differences on biological criteria between

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treatments through OFTs, it is equally important to determine farmers' reactions and perceptions about new technology.

OBJECTIVES OF OFR

Some objectives of OFR include:

- to verify performance of a new technology under farmers' conditions;
- to determine the range of farming systems under which the new technology offers promising results;
- to provide feedback to station researchers on the performance of a new technology in the farmers' fields and herds;
- to observe interactions between the technology and socio-economic parameters within agricultural communities, including gender-specific differences in the management and impact of new technologies
- to achieve participation of farm men, women and children in the development, testing, and evaluation of new technologies and management practices.

CONSIDERATIONS IN THE DESIGN OF OFR

OFR, of course, does often have a demonstration effect, but its main aim is to test technology and management practices before demonstration and extension takes place. OFR is therefore not the same as a demonstration trial! Various classifications of OFR are cited in the literature and the general term "on-farm experimentation" can also be applied. Literature distinguishes three types of on-farm experimentation:

- **exploratory trials** used in cropping systems research to test the technical feasibility of a new technology; farmers' participation is limited;

- **"adaptation trials"** or **"determinative trials"** with emphasis on technical aspects but farmers' reactions are also measured;
- **"verification"** or **"validation trials"** where farmers management is included as a variable, with emphasis on socio-economic aspects.

OFR can also be distinguished as **"researcher-managed"** and **"farmer-managed"**, the explanation of which should not be necessary. A further distinction can be made between **"trials"** and **"tests"**. "Trials" evaluate the technical merits of improved technology in farmers' fields and herds, while "tests" evaluate the economic viability and social acceptability of improved technology. On-farm experimental trials intend to show statistically significant effects of experimental treatments, often in relation to different categories of farming households. On-farm experimental tests are used to find out how the farm household and/or community handles the technology.

Selection of Technology

Treatments in OFTs are generally new, or modified technologies and management practices. Selection of either one of those for OFR depends on the screening of their suitability to local agro-ecological conditions, input availability and farmers' resources and objectives. (#1.3.3.). The needs and problems of farmers can be assessed through zoning and RRA's (#1.3.1. and #1.3.2.). Importantly, the social and cultural differences between farmers and within the family should be taken into account. It is not uncommon that when a new technology is tested, the men of the family will take part in all activities. However, once the activity becomes a routine, the women or children become responsible, even when the activity does not well fit into their labour films or priorities (#2.1.).

Design of On-Farm Trials

Experimental design follows the basic objectives of all research projects, but complicated experimental designs are difficult to manage on-farm. A minimal amount of hypothesis testing should be carried out. Data analysis should be expressed in simple biological and economic terms. Still, farmers' perceptions and suggestions are equally or more important than measurement of bodyweight gains. An experiment, whether on-station or on-farm, should never include too many treatments. In OFTs, single factor experiments are easiest to manage and interpret. On-farm livestock experimentation generally includes experimental controls, organized as follows :

- control and treatment animals on the same farm under similar management conditions; treatment effects not confounded with farm effects. This "**within approach**" is generally not suitable for farms with a small number of animals.
- non-participating farms can serve as controls, the "**with and without**" approach, but this may introduce a bias due to different management between farmers, it may also cause friction in the society, for example between neighbours.
- the period before and after the introduction of the technology can serve as control; the disturbing factors may be the seasonal effects, decrease in milk yield over the lactation in dairy-type animals and carry over effect. This "**before and after**" approach is only suitable for short-term experiments where no serious carry over effects are likely.

Due to the small numbers of animals on most Indian farms, the first method is seldom possible but it may be feasible at the village level where animals can be effectively segregated on different farms. For short-term trials, the third method is useful. For OFT where biological responses are expected the second method may be more appropriate.

Interactions and selection of experimental units

A major consideration in experimental design is the presence or absence of "a treatment x environment, or treatment x farm interactions", where the performance of a treatment is influenced by the characteristics of, or actions taking place on the farm(s) on which it is assigned. In case no interactions are expected, replication can be done at one site (farm) if the number of experimental units (plots, animals) are large enough. If interaction is expected (the more common case), replication should be done across farms. Treatment X farm interactions generally are less for varietal trials and more stable within land types. If the same land type across farms are selected, bias should be minimized. If treatment * farm interactions are expected, minimize replications per farm and maximize replications across farms. This equates farms with blocks and treatments are thus replicated across farms. This is particularly relevant in upland and rainfed areas where land types, farm resources and environments vary much more than lowland rice or plantation crop environments. Analysis of Variance (ANOVA), with farms equal to treatment blocks, cannot be used if there is a treatment X farm interaction. In such cases, it is better to use t-tests of mean differences with paired observations for each site and the post-stratification of sites.

Component Technology vs. Farmer-Managed Trials

The above trials, dealing with effects such as varietal performance, fertilizer response or strategic feeding of concentrates, are "component technology trials". Verification trials or farmer managed trials are simpler in nature and they allow wider evaluation of alternative technologies giving due consideration to farmers' perspective and economic and social acceptability. These trials usually involve only two treatments, with the farmer practice as control. Replication across a large number of farms is usually called for, generally 25-30 farms as a minimum, but the number may be different, depending on the type of treatment and expected response. Selection of sites and farms should be based on principles of recommendation domains which are generated by agro-ecological zoning and RRA's (#1.3.1. and #1.3.2.). Farmers' interest to cooperate is an essential part of the design of OFT's.

Treatments are assigned to experimental units. Selection of experimental units depends on the type of technology to be tested, categories of farm types for which a technology is designed, input availability, types of animals and herd structure, and status of each individual animal needed for the purpose of forming treatment groups. Experimental units can be animals when the treatment is expected to influence only animal performance or they can be farm households when the treatment is expected to influence labour use or allocation of capital within the farm. The more similar are the experimental units, the more precise the results of the experiment. However, the more homogeneous the experimental units, the smaller will be the range for which the experimental results are valid.

Farmers may well have their own objectives which differ from those followed in the experimental design, e.g., preferential feeding of sick animals. Moreover selection of treatments must consider researchers' or farmers' ability to measure the variables at the farm level. Weighing scales are usually not available to weigh large ruminants in the village and milk yield must often be adjusted for calf suckling. Frequency of data collection depends upon the nature of the trial, available resources, constraints and opportunities faced by the farm family (including women) in participating in data collection and measurement of biological parameters of the experiment.

Type of data to be collected

The major objective of OFR, and particularly of on Farm tests is to measure the farmer's reaction. That being so, it is important to focus the data collection as much as possible to the measurement of farmer's perception, men and women, experimental farmers and neighbours and so on. The use of open questions may complicate statistical elaboration of the data, but it is crucial to maximize the output of the tests. The measurement of biological responses like live weight gain, butterfat content or kilos dry matter and crude protein should therefore not draw attention away from issues such as: labour calendars, shifting workloads between men, women and children, or economic versus biological response. The BIOCON experience has shown that biological responses can be significant in on-station trials, but not statistically significant in variable field conditions. This should not only tell us to include more animals or fodder plots etc. in the OFT, it also represents a lesson that technologies that look so nice in on-station trials, may give different responses in the field. Also, whereas a biological response is not significant, it might be a reduction in expense or workload that is the real criterium why a farmer, his wife or their parents decide to adopt an innovation or not.

STATISTICAL PRINCIPLES AND CONCEPTS

Statistical analysis of livestock and crop residue OFR is necessary if one wants to draw valid inferences and conclusions about differences between treatments or between the treatment and control. It involves the collection, compilation, tabulation, analysis and interpretation of data sets. Knowledge is thus required about selection of experimental units (regions, farms, animals) and about statistical concepts. Therefore, it is important to choose appropriate statistical methods for the treatment of data. This section describes these basic concepts.

Sampling

Sampling is the process of choosing a representative group from the population. A sample is a number of individual units (e.g., farmers, cows, buffaloes, goats or sheep) selected from all those units that compose a population. The members of the sample must reflect the variations within the population so that the inferences drawn about the population on the basis of sample are valid and reliable. Sampling must be carried out systematically and the following considerations should be kept in mind:

- purpose of the investigation;
- size of the population;
- cost of collecting statistical data;
- time availability;
- nature of data to be collected.

Various sampling techniques are used to draw a sample, including methods such as non-random, or purposive sampling, probability sampling, random sampling, systematic sampling, stratified random sampling or multistage stratified random sampling. The selection of a sampling technique depends on the homogeneity of the population, the degree of precision required to separate treatment responses, and the researchers' need to control non-treatment variation. For further review of sampling procedures, the reader is encouraged to consult standard references on sampling techniques, such as given under suggested reading.

Selection of Sample Size

Sample sizes of OFR can be expected to vary widely, depending upon objectives of the trial and variability in the parameters to be measured. For most purposes, a sample size of 25-30 farms in each stratum for which an independent estimate is probably adequate to collect reliable quantitative information. When OFR emphasizes qualitative information (e.g., case studies), the number of farms per stratum may be less. The number of animals required in OFTs is a function of the variability of the biological parameter under investigation and the difference between treatments that the researcher regards as relevant. For example, milk yield is a highly variable parameter and there will thus be a large number of animals required to find significant differences between treatments. In drawing samples for the collection of field data, it is the sample size, and not the fraction of the population or group, that is important. For example, if the co-efficient of variation (CV) is 30 percent and the experiment is desired to have an 80 percent chance of detecting a 15 percent difference between treatments the sample size per treatment should be about 60. The sample size will be only

16 when the difference between treatments is expected to be 30 percent. Provided that the variation is known from previous trials, the minimum number of replications required is calculated as:

$$n = 2\,x\,t \quad \frac{CV^2}{d}$$

where:

- '*d*' is the least significant difference desired to be specified, i.e. the smallest difference between treatment means which is statistically significant.
- '*CV*' is the coefficient of variation and is determined as the mean divided by the standard deviation.
- '*t*' is determined from tables available in statistics textbooks and is usually selected to represent a 5 percent level of significance. The value of '*t*' is generally assumed to be 2 for sample sizes exceeding 20 at 5 percent significance level.

The smallest true difference, "*d*", to be detected should be specified by the researcher. The higher the predicted variation within the experimental units and the smaller the difference specified by the researcher, the more replications required. Usually, it is most convenient to express CV and d in percentages of the mean. If several population characteristics are of importance, the number of replications required should be calculated for the most variable characteristics.

Frequency of Sampling

Some examples of data collection schedules for different types of trials are given in Table 1. Sampling should be done as frequently as necessary to detect changes in the parameter of interest, but not so frequently as to cause disturbance to the animal or its owner and to significantly increase costs. Researchers often try to collect too much data, only to find later that half or less of the data collected is not useful. Weekly variation in bodyweight, for instance, is less important than monthly changes. Increasing sampling frequency does not necessarily increase the usefulness of the data to the separation of treatment effects.

Table 1 Examples of data collection schedules by types of trial

Type of trial effects on	Frequency
Testing new feeds	
Milk production	weekly / fortnightly
Bodyweight	fortnightly / monthly
Economic analysis	monthly
Labour calender	monthly
Task division	monthly
Testing of mineral mixture	
Calving interval	annually
Lactation length	annually
Dung consistency	in beginning weekly
Feed intake	in beginning weekly / fortnightly
Farmer's perceptions	monthly
Testing management practices like deworming	
Farmers perception	in beginning weekly
Body weight	fortnightly
Milk production	fortnightly

Statistical analysis

The statistical analysis of data from OFTs may be as simple as calculation of averages and standard deviations followed by preparation of graphs. Student's 't-test' can be used to test the significant difference between control and treatment means. Paired 't-test' should be used whenever it is possible to pair the animals or farms according to weight, age, feeding practices, etc. Non-parametric tests such as sign test and Wilcoxon signed-rank tests can also be used whenever the underlying population distribution is not known. Analysis of variance (ANOVA) is used whenever comparisons among several treatment means is to be made and the volume of data is large. Least squares analysis for non-orthogonal data can also be used when the number of observations in each treatment class are unequal provided there is sufficient data.

Correlation and regression analysis is useful to determine if, and how a certain variable is influenced by other variables. The first step is development of a suitable statistical model which relates the variables one to the other. The suitability of a model depends upon the types of data and the objectives of on-farm trial. For more details on design of experimental trials and specific models to process and interpret data from OFT, the reader is again referred to suggested reading.

CONCLUSION

On farm research is part and parcel of the FSR/E procedures. Though OFT's will result in some demonstration effect, their primary purpose is to precede extension and demonstration. Different degrees of farmers' and scientists' involvement in the trial management can be found, depending on the objective of the studies. Though statistical analysis is important, it may often be difficult due to large variation in the field : a lesson for those who want to translate on-station research into extension messages without testing the actual responses in the field. Questions may have to be open ended in order to encourage farmers perception to become clear, and the "loss of statistical reality" is a small price to pay. The statistical procedures can involve a set of techniques, mainly applying simple methods due to the lower number of treatments that can be accommodated in on-farm research. Though the measurement of biological response is important, it should be remembered that the primary aim of on-farm experiments is to study the introduction of the new technology in farmers condition. Economical, sociological, gender related aspects and farmers modifications are important to be elicited in the first place, and they should not be neglected in favour of measuring biological effect.

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